ISSN 1936-878X/09/$36.00

PUBLISHED BY ELSEVIER INC.

DOI:10.1016/j.jcmg.2009.08.010

Ultra-Low-Dose Intra-Arterial Contrast Injection for Iliofemoral Computed Tomographic Angiography

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OBJECTIVES This study sought to evaluate the feasibility of using ultra-low-dose intra-arterial contrast injection for iliofemoral computed tomographic (CT) angiography to follow diagnostic cardiac catheterization.

BACKGROUND Cardiovascular interventions such as percutaneous aortic valve replacement require transfemoral delivery of large-bore intra-arterial catheters; therefore, pre-procedural assessment of aortoiliofemoral anatomy is important. CT angiography is ideal for this purpose but requires a large volume of intravenous contrast.

METHODS Consecutive patients requiring evaluation of aortoiliofemoral anatomy underwent conventional anteroposterior projection iliac angiography during cardiac catheterization. A pigtail catheter was left in situ in the infrarenal abdominal aorta, and patients were transferred to the CT suite. Subsequently, 10 to 15 ml of contrast diluted with normal saline was injected intra-arterially via the pigtail catheter while a spiral CT of the abdomen and pelvis was acquired. Conventional angiographic and CT images were analyzed independently to assess suitability for large-bore (7-mm-diameter) intra-arterial catheter access.

RESULTS Excellent CT image quality was achieved in 34 of 37 patients (92%). The mean contrast dose for CT was 12 $\pm$ 2 ml. In 9 patients (24%), CT changed the assessment of femoral access feasibility. Furthermore, in another 7 patients (19%), unfavorable anatomy as shown by CT directed the avoidance of a particular side. Overall, CT findings altered the interventional approach in 16 patients (43%). There was no significant deterioration detected in renal function after coronary and CT angiography (estimated glomerular filtration rate 54.8 $\pm$ 3.8 ml/min before 53.3 $\pm$ 3.9 ml/min after, $p = 0.55$).

CONCLUSIONS High-quality aortoiliofemoral CT angiography can be obtained with a technical success rate of >90% using 10 to 15 ml of contrast injected via a catheter in the abdominal aorta, and offers an alternative to conventional X-ray or CT angiography with high-volume intravenous contrast injection. (J Am Coll Cardiol Img 2009;2:1404–11) © 2009 by the American College of Cardiology Foundation

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Manuscript received May 4, 2009; revised manuscript received July 30, 2009, accepted August 5, 2009.

Trauma to the femoral and iliac arteries is a recognized complication of percutaneous cardiac interventions (1). Percutaneous aortic valve replacement is a new procedure that carries a high risk for this complication because it requires delivery of a large-diameter (22-F) catheter (2–6). The risk is further increased by the high prevalence of peripheral arterial disease in the elderly patient population for whom percutaneous aortic valve replacement is considered (7,8). Preprocedural evaluation of the iliac and femoral arteries is therefore crucial both for patient selection and to guide the intervention.

Imaging of the iliofemoral arterial tree is often performed by conventional X-ray angiography (CA) in the cardiac catheterization laboratory. Computed tomographic (CT) angiography provides more anatomical detail; however, the 50- to 140-ml intravenous contrast load required carries a substantial risk of contrast-induced nephropathy, particularly when performed in addition to other studies such as coronary angiography (9–12). We hypothesized that direct intra-arterial injection of contrast would allow for a lower dose of contrast by avoiding the dilution that occurs with transit through the circulation. Given that arterial access has already been established, we developed a protocol for intra-arterial contrast injection computed tomographic angiography (IA-CTA) to follow diagnostic cardiac catheterization.

METHODS

The study population consisted of patients being considered for percutaneous aortic valve intervention. Patients gave informed consent for CT angiography with intra-arterial contrast injection. The protocol for this research study was approved by the institutional review board.

Diagnostic coronary angiography was performed on all patients. For iliofemoral CA, a 5-F marker pigtail catheter (Cook, Bloomington, Indiana) was placed in the abdominal aorta distal to the renal arteries. Contrast was delivered via a power injector using 15 to 25 ml of contrast at a rate of 10 to 15 ml/s, and images were obtained via cineangiography or digital subtraction angiography at the discretion of the operator. Quantitative measurements were performed at the time of the procedure using 2 consecutive markers as a 10-mm reference. Serial measurements were made bilaterally in the proximal and distal segments of the common iliac, external iliac, and common femoral arteries.

The catheter was then exchanged for a standard 4- or 5-F pigtail catheter to minimize the CT imaging artifact. The catheter was left in situ with its tip in the infrarenal abdominal aorta, connected to heparinized saline, and secured in place with adhesive dressings. Patients were immediately transferred to the CT suite located adjacent to the cardiac catheterization laboratory.

The CT scanning was performed on a 64-detector-row cardiac system (Brilliance 64, Philips Medical Systems, Best, the Netherlands). After the survey scan, a noncontrast helical CT of the chest, abdomen, and pelvis was acquired to assess for arterial calcification. The location of the pigtail catheter was also confirmed using this scan, and when necessary, the catheter was repositioned with the tip in the infrarenal abdominal aorta. If catheter repositioning was necessary, the noncontrast scan was not repeated because the CT allowed for accurate measurement of the distance the catheter needed to be withdrawn. Iodinated contrast (iopamidol 370 mmol/ml) was mixed with normal saline in a 1:3 to 1:4 dilution in a single chamber of the power injector. The power injector was connected to the pigtail catheter using sterile technique with care taken to exclude all air; 40 ml of the contrast/saline mixture was injected at 4 ml/s through the pigtail catheter without a saline chaser. After a scan delay of 6 s, a helical CT of the abdomen and pelvis was acquired (64 × 0.625-mm collimation, rotation time 0.75 s, pitch 0.64, 120 kV, 154 mAs). Immediately after the acquisition, the pigtail catheter was removed while the patient was in the CT suite. The femoral arterial sheath was left in situ to be removed after the patient's return to the cardiac catheterization recovery area.

ABBREVIATIONS AND ACRONYMS

CA = conventional angiography

CT = computed tomography

IA-CTA = intra-arterial contrast injection computed tomographic angiography

Image analysis. The images were analyzed by 2 cardiologists (D.H.S. and S.B.J.). A consensus opinion was reached regarding the suitability for large-bore intra-arterial access for each femoral artery based on tortuosity, calcification, focal stenosis, and overall vessel caliber. The minimum diameter of the distal abdominal aorta, common iliac arteries, external iliac arteries, and common femoral arteries were recorded.

The contrast-enhanced IA-CTA images were assessed using commercially available software (Extended Brilliance Workspace version 3.5, Philips Healthcare). Three-dimensional volume-rendered images were created to assess tortuosity (Fig. 1), and multiplanar reformations were created manu-

JACC: CARDIOVASCULAR IMAGING, VOL. 2, NO. 12, 2009
DECEMBER 2009:1404–11

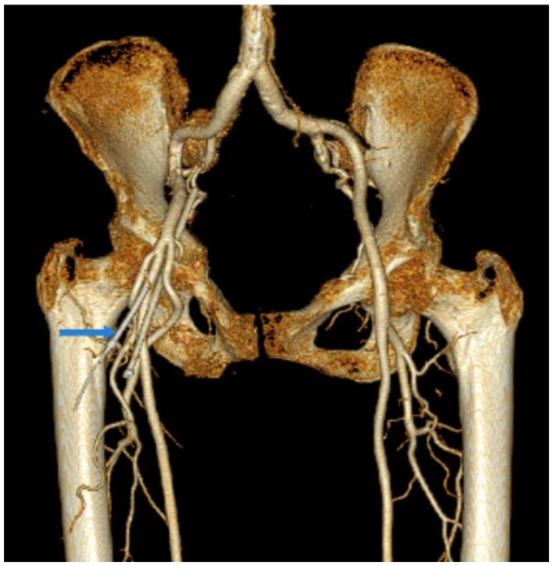

Figure 1. 3-Dimensional Image From CT Angiogram

Volume-rendered image of intra-arterial computed tomography (CT) angiogram obtained with 10 ml of intra-arterial contrast injection. The catheter and sheath can be seen entering the right common femoral artery **(arrow)**.

ally to obtain a cross-section of the vessel perpendicular to its long axis for the assessment of caliber (Fig. 2). The window level was chosen for optimal visualization of the contrast-filled lumen and to allow differentiation from vascular calcification. The 2 observers (D.H.S. and S.B.J.) reached a consensus opinion regarding suitability for femoral access, with a third observer (A.R.) for adjudication in case of disagreement.

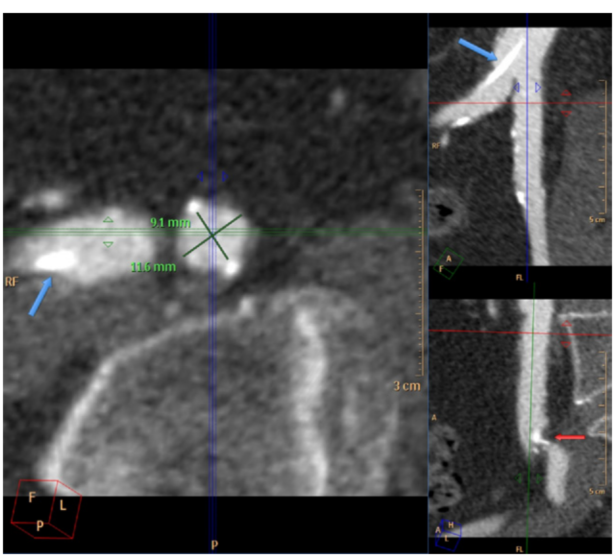

Figure 2. Intra-Arterial CT Angiogram

Multiplanar reformatted images of intra-arterial computed tomography (CT) angiogram. The cross-sectional minimal luminal diameter is measured perpendicular to the long axis of the vessel. The catheter is visible in the aorta and right common iliac artery **(blue arrows)**, and there is calcified plaque evident in both common iliac arteries. In the **bottom right image**, calcification is noted at the ostium of the left internal iliac artery **(red arrow),** although the true reduction in luminal diameter cannot be assessed on this imaging plane.

The same criteria for suitability of vascular access were used for both CA and IA-CTA. Vessel caliber was deemed inadequate if the minimum diameter was <7 mm. This threshold was based on the diameter of the current percutaneous aortic valve delivery system. Percutaneous cardiac intervention was also considered contraindicated in the presence of severe iliofemoral artery tortuosity (>135° change in vessel course), moderate tortuosity (>90° change in course) associated with circumferential calcification, or extensive arterial dissection. Observers also provided a binary qualitative assessment of their diagnostic confidence. Images acquired with both techniques were deidentified and read in random order to allow for independent assessment.

Statistical analysis. All statistical analyses were performed using Stata version 10.0 (StataCorp, College Station, Texas). Vessel dimensions as measured on CA and IA-CTA were compared using a Pearson correlation coefficient. The Student's paired *t* test was used to compare renal function and contrast doses with the 2 techniques, whereas the McNemar test (exact) was used to compare diagnostic confidence. Continuous variables were expressed as means with standard deviations, and a value of $p < 0.05$ was considered statistically significant.

RESULTS

Thirty-seven (37) patients were studied (mean age 84 ± 6 years, 22 women, 13 with diabetes). The IA-CTA imaging protocol was successfully completed in all 37 patients, with a mean contrast dose of 12 ± 2 ml. Renal function at baseline and 72 h after IA-CTA was not significantly different (estimated glomerular filtration rate 54.8 ± 3.8 ml/min vs. 53.3 ± 3.9 ml/min, $p = 0.55$).

Image quality was excellent in 34 patients (92%), allowing visualization of the entire vessel lumen from the aortic bifurcation to the common femoral arteries. In 2 patients, distal contrast opacification was suboptimal because of discordant timing of scan acquisition and contrast injection. In these 2 cases, the table speed surpassed that of the contrast bolus, outrunning the contrast. Increasing the scan delay to 6 s after contrast administration prevented further occurrence of this problem. In 1 patient, the

Table 1. Contraindications to Large-Bore Femoral Arterial Access As Assessed on Conventional and Computed Tomographic Angiography

	Severe Tortuosity	Circumferential Calcification	Diameter <7 mm	Arterial Dissection
CA	11	0	20	0
IA-CTA	13	3	28	1

CA = conventional angiography; IA-CTA = intra-arterial computed tomographic angiography.

pigtail catheter tip was situated above the origin of the renal arteries, resulting in poor vessel opacification and an uninterpretable scan. One case was complicated by thrombosis of the pigtail catheter lumen. The catheter was replaced through the femoral artery sheath, and the scan was completed without clinical sequelae. There were no local vascular complications in any of the 37 patients.

On a per-vessel basis, 43 of 74 femoral arteries (58%) were deemed suitable for large-bore intra-arterial access based on CA. In several instances, multiple contraindications were noted in the same vessel (Table 1). By IA-CTA, contraindications were uncovered in 17 of the 43 femoral arteries (40%) deemed suitable by CA. These consisted of inadequate caliber or focal stenosis in 12 arteries, severe tortuosity in 2 arteries, severe circumferential calcification associated with tortuosity in 2 arteries, and localized severe arterial dissection in 1 artery (Figs. 3 to 6). Conversely, in 6 instances, IA-CTA suggested that femoral access was possible when CA suggested it was not. In 3 of these cases, the initial contraindication based on CA was inadequate caliber or focal stenosis, whereas in another 3 cases it was severe tortuosity.

On a per-patient basis, femoral access was deemed possible in 27 of 37 patients (73%) based on CA, and neither femoral artery was suitable in 10 patients. The additional imaging by IA-CTA changed the overall patient classification from suitable to unsuitable in 8 patients, whereas in 1 patient IA-CTA suggested that femoral access was possible when it was previously thought to be contraindicated based on CA. Furthermore, IA-CTA suggested that 1 side (1 femoral artery) should be avoided in 7 patients because of a unilateral contraindication not appreciated on CA. Overall, IA-CTA findings would have altered the interventional approach in 16 patients (43%).

Of the 19 patients with anatomy deemed suitable for femoral access based on IA-CTA, percutaneous aortic valve replacement was attempted in 9 patients. In all cases, femoral arterial access and catheter delivery through the iliofemoral system was successful. Percutaneous aortic valve replacement was not attempted in any patient with anatomy deemed unsuitable based on IA-CTA.

The mean contrast dose was significantly lower for IA-CTA than for CA (12 ± 2 ml vs. 17 ± 3 ml, $p < 0.001$). Diagnostic confidence was also significantly higher for IA-CTA than CA, with certainty regarding the assessment of suitability in 68 (92%) and 53 (72%) vessels, respectively ($p = 0.004$). The correlation between IA-CTA and CA measurements was good ($r = 0.92$, $p < 0.001$); however, there was a systematic underestimation of size by

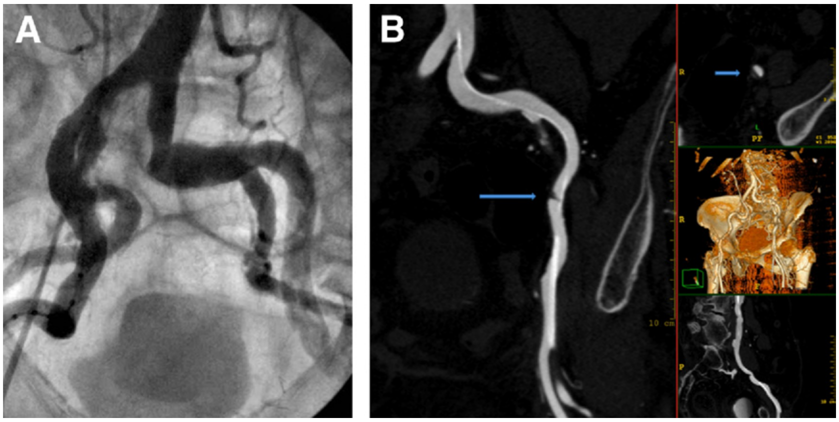

Figure 3. Focal Arterial Stenosis

(A) Conventional angiogram. **(B)** Intra-arterial computed tomography angiogram of the same patient revealing severe focal left iliac artery stenosis **(arrow)** on curved multiplanar reformatted images. The **top right inset image** shows the reduction in lumen size with the vessel in cross-section, the **middle inset image** is a volume-rendered image, and the **bottom inset image** is another curved multiplanar reformation orthogonal to the main image.

JACC: CARDIOVASCULAR IMAGING, VOL. 2, NO. 12, 2009
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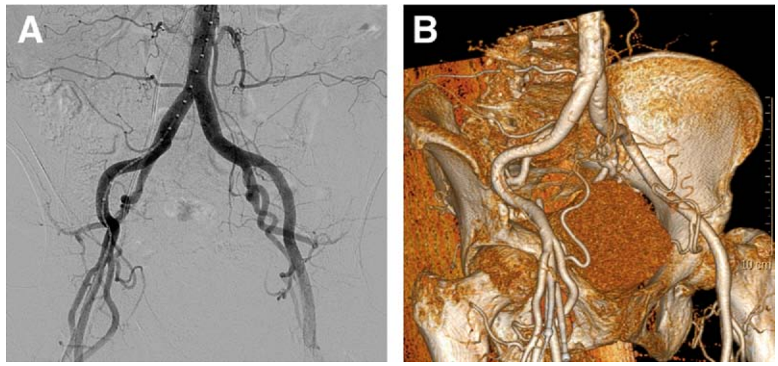

Figure 4. Tortuous Course

(A) Conventional angiogram. **(B)** Volume-rendered image of an intra-arterial computed tomography angiogram of the same patient, confirming marked tortuosity of the right iliac artery as it courses posteriorly in the pelvis.

CA with a mean difference of 1.0 ± 1.6 mm ($p < 0.001$) (Fig. 7).

DISCUSSION

We describe a novel technique for CT angiography of the iliofemoral arterial tree that uses only 10 to 15 ml of iodinated contrast. Traditional techniques for imaging the iliac arteries have significant limitations. Each 2-dimensional acquisition during CA requires approximately 15 to 30 ml of contrast, and therefore usually only 1 projection is obtained. Rotational C-arm systems may allow for better assessment of tortuosity; however, limitations regarding measurement of lumen caliber and plaque morphology are likely to remain (13). New multidetector scanners have made rapid CT angiography feasible, allowing for the acquisition of 3-dimensional datasets that can be viewed in any imaging plane (14). Computed tomography also allows for the identification of both calcified and noncalcified plaque (15). However, the intravenous contrast volume required for standard abdominal and pelvic CT angiography carries the risk of contrast-induced nephropathy (11).

Contrast-induced nephropathy is an important complication of angiography. Risk factors include older age, chronic kidney disease, diabetes mellitus, and high volumes of iodinated contrast (16). Patients undergoing percutaneous aortic valve replacement are likely to be particularly susceptible to contrast-induced

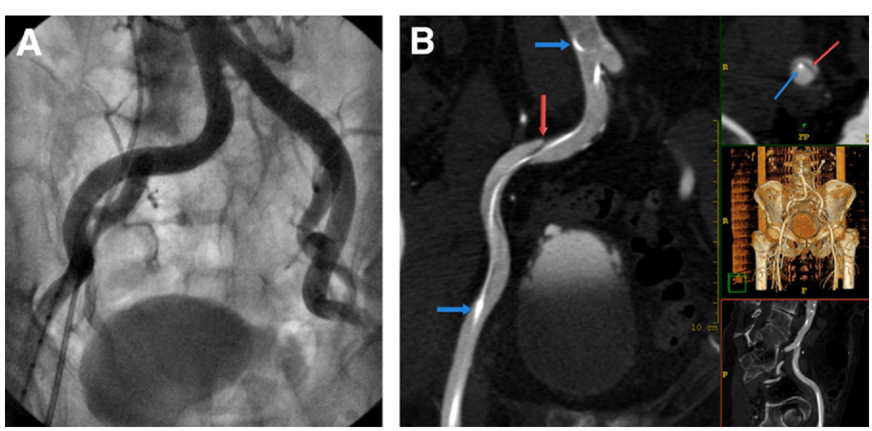

Figure 5. Arterial Dissection

(A) Conventional angiogram. **(B)** Curved multiplanar reformatted images of an intra-arterial computed tomography angiogram revealing extensive dissection of the right iliac and femoral arteries. The intimal flap **(red arrows)** and its association with the catheter **(blue arrows)** can be seen. (The dissection is likely to have been iatrogenic as part of the diagnostic cardiac catheterization and had no clinical sequelae).

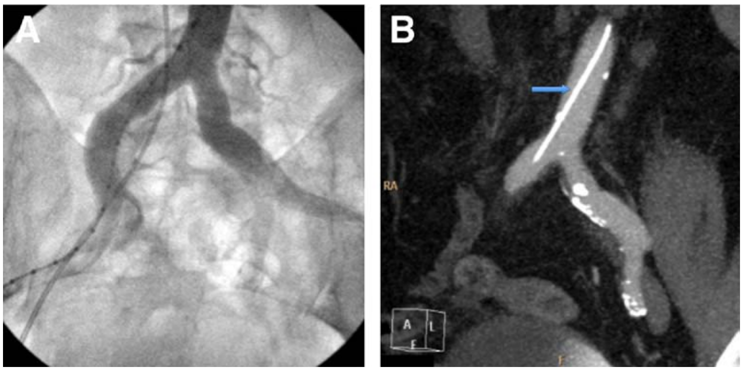

Figure 6. Atherosclerotic Plaque

(A) Conventional angiogram. **(B)** Maximum-intensity projection reformatted image of an intra-arterial computed tomography angiogram revealing calcified atherosclerotic plaque in the proximal left common iliac artery. The catheter is also visible **(blue arrow)**.

nephropathy by virtue of being elderly with multiple comorbid illnesses that have placed them at prohibitively high risk for cardiac surgery. Our technique allows for a dramatic reduction in contrast dose and makes iliofemoral CT angiography feasible after cardiac catheterization (9,12). Gadolinium-enhanced magnetic resonance angiography is an alternative technique that would avoid the high volumes of iodinated contrast; however, the risk of nephrogenic systemic fibrosis would limit its use in patients with impaired renal function.

In this study, IA-CTA provided clinical information that would have changed management in a substantial proportion of patients. Although CA was performed in our patients for comparison, the IA-CTA technique is intended as an alternative rather than an additional test. The ability to perform multiplanar reformations with CT allowed for accurate assessment of vessel diameter by providing a cross-section of the vessel perpendicular to its course in 2 orthogonal planes. Volume-rendered images were used to identify tortuosity and not for the assessment of caliber because of the known variability in vessel dimensions related to window level settings (17). We chose the diameter of the catheter used for percutaneous aortic valve replacement, 7 mm, as the threshold for feasibility of arterial access. Our criteria were based on clinically relevant findings that are considered contraindications to large-bore femoral arterial access for other endovascular procedures (18–20). In addition to percutaneous valve replacement, IA-CTA may be useful before other endovascular or surgical procedures when arterial anatomy needs to be clearly delineated (21,22).

The poor CT image quality noted in 3 cases was related mainly to catheter position and timing. With our IA-CTA technique, the duration of contrast opacification is short and scan acquisition must be timed carefully to match. Initially a 4-s scan delay was used, but this was increased to 6 s to avoid outrunning the contrast. A longer contrast injection would allow for a longer timing window but would increase the contrast volume, albeit only slightly. Artifact caused by calcification was noted in our patients, and this could hinder the assessment of vessel caliber (23). There is potential for artifacts related to the catheter or heterogeneous inflow of contrast; however, no such phenomena were noted in our images.

The imaging protocol we describe does carry some risk. There are hazards associated with obtaining femoral arterial access; however, these have

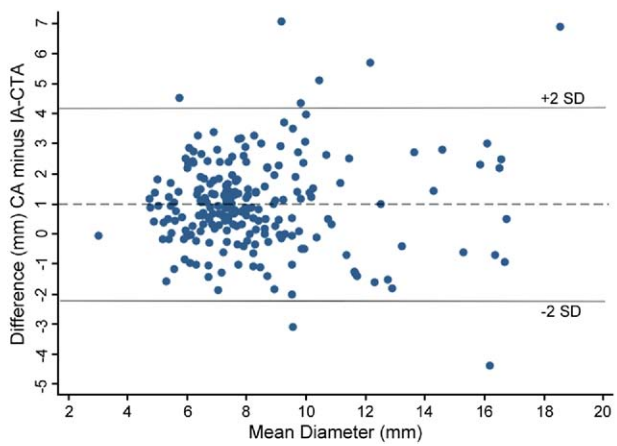

Figure 7. Bland-Altman Plot

Bland-Altman plot showing a 1-mm overestimation of vessel diameter by conventional angiography (CA) compared with intra-arterial contrast injection computed tomographic angiography (IA-CTA), and limits of agreement.

already been accepted as part of the preceding diagnostic cardiac catheterization. Thrombosis of the pigtail catheter lumen occurred in 1 patient in our study, emphasizing the need for rapid transport and use of heparinized saline to maintain patency of the catheter. The time between the last CA series and the final IA-CTA acquisition was approximately 60 min, including the time for transfer with the femoral sheath and pigtail catheter secured in situ. The radiation dose for the IA-CTA technique we describe is also high. Although not collected as part of this study, on subsequent patients the average dose–length products were 1,955 mGy·cm and 1,459 mGy·cm for the noncontrast and contrast-enhanced portions of the scan, respectively, corresponding to effective doses of approximately 27 (range 20 to 36) mSv and 20 (range 5 to 26) mSv. Although radiation is less of an issue in the elderly population studied, it would limit the use of this approach in younger individuals (24). Alterations in the pitch, current, and voltage settings would allow for significant reductions in radiation dose (14,25).

CONCLUSIONS

Aortoiliofemoral CT angiography can be performed with a technical success rate of >90% using 10 to 15 ml of contrast injected via a catheter in the abdominal aorta. The novel protocol we describe to follow cardiac catheterization offers an alternative to conventional fluoroscopic angiography or CT angiography with high-volume intravenous contrast injection.

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Key Words: angiography ■ computed tomography ■ peripheral vascular disease ■ percutaneous aortic valve replacement.